Description

WORK SITE DUST CONTROL SYSTEM

Technical Field

[01] The present invention relates generally to the control of work site dust conditions and, more particularly, to the application of one or more dust control machines to treat work site dust conditions.

Background

[02] In various industries, such as the mining industry and the construction industry, work site operations may occur within or may cause undesirable dust conditions. For example, cutting or other mining operations at a mining site may significantly increase dust levels at the site. Such increased dust levels may cause undesirable conditions, such as impaired visibility within the site, diminished work machine performance, and increased frequency of work machine maintenance. Moreover, such dust levels may create uncomfortable work conditions for work personnel.

[03] Various devices and methods have been used in the past to control work site dust conditions. For example, U.S. Patent No. 4,714,293 discloses a dust control apparatus for use at a mining site during operation of a cutting tool. The apparatus includes means for dispersing pressurized water toward the cutting tool during a cutting operation.

[04] U.S. Patent No. 4,380,353 discloses a method for controlling dust generated by the operation of mining equipment. The method includes using a fan to remove dust-laden air from the vicinity of a work operation during performance of the work operation, directing the dust-laden air through a passage, using water to scrub dust from the air as it flows through the passage,

separating dust-laden water droplets from the air, and disposing of the dust-laden droplets.

[05] Another method of controlling work site dust conditions includes using a water truck to spray water generally about a work site. Such a water truck typically roams a work site from one work location to another, often over or under treating the work site.

[06] Prior methods of controlling work site dust conditions may suffer from various disadvantages. For example, prior methods may focus dust treatment measures at a particular work location only during the performance of a disruptive work operation, such as a cutting operation. Thus, prior methods may not sufficiently prevent or otherwise control dust conditions at a work location when disruptive work operations are not occurring. Moreover, prior methods may not effectively or efficiently deploy dust control equipment throughout a work site. For example, prior methods may not effectively manage dust treatment operations among multiple work locations, nor effectively manage the deployment of multiple dust control machines. Further, prior methods may cause inefficient treatment of dust conditions, for example by over or under treating a work site.

[07] The present invention is directed to overcoming one or more disadvantages associated with prior dust control devices and methods.

Summary of the Invention

[08] In one embodiment of the present invention, a method for controlling work site dust conditions is provided. The method may include providing a mobile dust control machine configured to treat a dust condition within a work location. The dust control machine may be disposed distant from the work location. The method may further include monitoring a dust condition of the work location, generating a dust control signal in response to monitoring the dust condition, dispatching the mobile dust control machine to the work

location in response to the dust control signal, and operating the mobile dust control machine at the work location.

[09] In another embodiment of the present invention, a dust control system for controlling work site dust conditions is provided. The system may include a dust monitor disposed and arranged to monitor a dust condition of a work location and being operable to produce a dust control signal. The system may further include a mobile dust control machine configured to treat a dust condition within the work location, the dust control machine being movable to the work location from a position distant from the work location in response to the dust control signal.

[10] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

Brief Description of the Drawing

[11] The accompanying drawing, which is incorporated in and constitutes a part of this specification, illustrates exemplary embodiments or features of the invention and, together with the description, serves to explain the principles of the invention. In the drawing,

[12] Fig. 1 is a diagrammatic illustration of an exemplary dust control system.

[13] Although the drawing depicts exemplary embodiments or features of the present invention, the drawing is not necessarily to scale, and certain features may be exaggerated in order to better illustrate and explain the present invention. The exemplifications set out herein illustrate exemplary embodiments or features of the invention and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

Detailed Description

[14] Reference will now be made in detail to embodiments or features of the invention, examples of which are illustrated in the accompanying drawing. Wherever possible, the same or corresponding reference numbers will be used throughout the drawing to refer to the same or corresponding parts.

[15] Referring to Fig. 1, an exemplary dust control system 10 is shown. The dust control system 10 may be used to control dust conditions within one or more work locations 14a, 14b, 14c. The dust control system 10 may include one or more mobile dust control machines 18a, 18b, one or more dust monitors 22a, 22b, 22c, and a controller 26.

[16] In one embodiment of the present invention, a work site may be divided into one or more work locations 14a, 14b, 14c or zones. It should be appreciated that the work locations 14 may be proximate each other or may, alternatively or additionally, be distant from each other.

[17] Each mobile dust control machine 18 may be configured to treat a dust condition within one or more work locations 14 and may include dust control equipment 30. The dust control equipment 30 may comprise, for example, any of a variety of dust control devices known in the art. An exemplary arrangement of dust control equipment 30 may include a water reservoir 31, a water pump (not shown), and a spray nozzle 32 for delivering pressurized water to a desired work location 14. A variety of known water spray techniques may be used to reduce dust levels at a work location 14. It should be appreciated that alternative or additional types of dust control equipment 30 and/or techniques known in the art may be used with the dust control system 10 disclosed herein.

[18] Each dust control machine 18 may be movable to and from one or more work locations 14. For example, a dust control machine 18 may comprise a mobile work truck including a steering mechanism (not shown) and being movable to a desired location by work personnel. In one embodiment, a dust control machine 18 may be a remote-controlled work vehicle capable of

traversing a work area. It should be appreciated that alternative or additional types of dust control machines 18 known in the art may be used in accordance with the present invention.

[19] One or more work locations 14a, 14b, 14c may be monitored, for example by a dust monitor 22a, 22b, 22c, to determine dust conditions at the work location 14a, 14b, 14c. For example, a dust monitor 22a positioned at or proximate a work location 14a may include dust monitoring equipment. In one embodiment, a dust monitor 22a may be operable to sample air at the work location 14a to determine a dust condition at the work location 14a, such as a dust level at the work location 14a. An exemplary dust monitoring technique may include using dust monitoring equipment to collect dust-laden air from the work location 14a, using a constant intensity light source to pass light through the dust-laden air toward a light sensor, and measuring the magnitude of light transmission interference between the light source and the light sensor. The magnitude of the interference may be used to indicate the density of dust contained in the air. It should be appreciated that alternative or additional types of dust monitoring devices or methods known in the art may be used with the dust control system 10.

[20] Each dust monitor 22a, 22b, 22c may be operable to produce a dust control signal 34a, 34b, 34c indicative of a dust condition at a work location 14a, 14b, 14c. In one embodiment, a dust control signal 34 may comprise a radio frequency type signal, an electrical type signal, or other type signal indicative, for example, of a level of dust present at a work location 14. Moreover, a dust monitor 22 may be operable to transmit a dust control signal 34 that is proportional to the level of dust present at the corresponding work location 14. Alternatively or additionally, the dust control signal 34 may comprise a signal indicating that the level of dust in the work location 14 is above, or is predicted to rise above, a reference dust level -- *e.g.*, a desired, undesired, optimum, minimum, or maximum dust level, for example. Moreover, a dust control signal

34 may comprise a signal indicating that the level of dust in the work location 14 is below, or is predicted to fall below, a reference dust level. The reference dust level may be, for example, a predetermined dust level in accordance with federal, state, or local laws or regulations. Alternatively or additionally, the reference dust level may be a subjectively or objectively determined dust level that may be predetermined or determined in real time by work personnel. Further, a dust monitor 22 may be configured to monitor a dust condition at a work location 14 periodically, continuously, selectively, when activated by work personnel, or according to any of a variety of time intervals, conditions, or sampling techniques.

[21] Each dust monitor 22 may be configured to transmit a dust control signal 34 independent of, or in one embodiment in lieu of, its dust monitoring function. For example, a dust monitor 22 may, alternatively or additionally, be configured to allow work personnel to cause the dust monitor 22 to transmit a dust control signal 34 manually or automatically. In one exemplary embodiment, a dust monitor 22 may have controls (not shown) that may be manually operated by work personnel to produce a desired dust control signal 34. Thus, a dust condition, or an expected dust condition, of a work location 14 may be determined by work personnel, who may cause the dust monitor 22 to generate a corresponding dust control signal 34.

[22] It should be appreciated that when a plurality of dust monitors 22a, 22b, 22c are used, the dust monitors may be configured to monitor their respective work locations 14a, 14b, 14c independently, simultaneously, consecutively, or in any other desired manner. Moreover, the dust monitors 22a, 22b, 22c may be mounted in fixed locations or positions or may be movable to a variety of positions or work locations 14a, 14b, 14c.

[23] In one embodiment, a dust monitor 22d may be mounted on a work machine 38 -- such as a track-type tractor, a grading machine, a paving machine, a dust control machine, or the like -- that is positioned within or

movable to a work location 14a. Further, the dust monitor 22d may be movable from one work location 14 to another, for example, along with the work machine 38 if the work machine 38 is a mobile work machine. When mobile dust monitors 22d are used, each mobile dust monitor 22d may be associated with locating equipment 24 such as a Global Positioning System (GPS) for example, so that the position of the dust monitor 22d may be tracked, such as by the controller 26, and associated with an appropriate work location 14a.

[24] In one embodiment, a mobile dust monitor 22e may be mounted to a dust control machine 18a. In such an embodiment, the dust monitor 22e may be used to determine dust conditions proximate the dust control machine 18a, for example within a work location 14 in which the dust control machine 18a is performing dust treatment operations.

[25] In an embodiment where fixed location dust monitors 22 are used, each fixed location dust monitor 22 may be configured and arranged to monitor more than one work location 14. For example, a dust monitor 22 may be arranged proximate two or more work locations 14 such that monitoring of multiple work locations 14 may be accomplished with a single dust monitor 22. Such a dust monitor 22 may be operable to transmit dust control signals corresponding to and distinguishing the dust conditions of the respective monitored work locations 14.

[26] Referring again to Fig. 1, the dust control system 10 may include one or more controllers 26. A controller 26 may include a computer processor and/or other electrical control componentry. Moreover, the controller 26 may be operable to communicate with one or more dust monitors 22. For example, the controller 26 may be configured and arranged to communicate with the dust monitors 22 by wireless communication means, such as by satellite, cellular, or radio frequency technology, which means are generally well known. Alternatively or additionally, the controller 26 may communicate with the dust monitors 22 by other means, such as a modem having access to public telephone

lines. Alternatively or additionally, the controller 26 may communicate with the dust monitors 22 via wired communication means, such as a wired system connecting the dust monitors 22 and the controller 26. It should be appreciated that additional or alternative communication means may be used between the controller 26 and the dust monitors 22 in accordance with the present invention. It should further be appreciated that a controller 26 may be positioned at a variety of locations, such as on a dust control machine 18, within or adjacent a dust monitor 22, or distant from all dust control machine(s) 18 and/or dust monitor(s) 22, for example.

[27] The controller 26 may be operable to receive one or more dust control signals 34a, 34b, 34c, 34d from one or more dust monitors 22a, 22b, 22c, 22d, 22e via the communication means. The controller 26 may use the dust control signals 34 to produce one or more dispatch signals 42 for dispatching (*e.g.,* deploying) one or more of the dust control machines 18 to one or more work locations 14. For example, the controller 26 may respond to the one or more control signals 34 by determining that a particular mobile dust control machine 18a should be dispatched to a particular work location 14a, and may therefore produce a dispatch signal 42 for dispatching the appropriate dust control machine 18a to that work location 14a.

[28] It should be appreciated that a dust control signal 34 received by the controller 26 may indicate a specific dust level within a specific work location 14, and the controller 26 may be operable to compare the indicated dust level to a reference dust level or dust condition to determine whether dust treatment operations within the specific work location 14 are warranted. Similarly, a plurality of dust control signals 34 received by the controller 26 over a period of time may be evaluated by the controller 26 to identify a dust level trend within the specific work location 14, and the controller 26 may be operable to compare the trend to a reference dust level or trend to determine whether dust treatment operations within the specific work location 14 are warranted. Alternatively or

additionally, a dust control signal 34 itself may indicate that a dust level, or a dust level trend over a period of time, within a work location 14 is above, below, substantially equal to, or bears some other relationship to a reference dust level or dust condition such that dust treatment operations within the work location 14 are warranted. In any case, the controller 26 may respond to the dust control signal or signals 34 by producing a dispatch signal 42 for dispatching a dust control machine 18 to or away from a work location 14, as appropriate. Similarly, the controller 26 may respond to the dust control signal or signals 34 to cancel a dispatch signal 42 or otherwise terminate a dust treatment operation when the dust control signal or signals 34 indicate that a dust condition at a work location 14 has been sufficiently treated or otherwise sufficiently changes. For example, after a dust control machine 18 has been dispatched to and has performed dust treatment operations within a specified work location 14, a dust monitor 22 at the work location 14 or onboard the dust control machine 18 may indicate that dust conditions within the work location 14 have been sufficiently treated. Thereafter, the dust control machine 18 may move to the next work location 14 on its dispatch route, or, alternatively, the dust control machine 18 may be immediately dispatched to a different work location 14 by the controller 26.

[29] A dispatch signal 42 may comprise, for example, an electrical type or other type signal that is communicated to a dust control machine 18 or to an operator that is operating the dust control machine 18. For example, the dust control machine 18 may include a visual operator display (not shown), and the dispatch signal 42 may be automatically communicated by the controller 26 to the operator display via a communication means, such as one of the communication means discussed above. The dispatch signal 42 may be transmitted to the operator display to provoke or instruct a machine operator to move the dust control machine 18 to a specific work location 14 to perform a dust treatment operation.

[30] In an alternative embodiment, a dispatch signal 42 may comprise a visual or audible indication at the controller 26, at a dispatch station (not shown), or at some other location distant from the work location 14 and/or the dust control machine 18. For example, the indication may indicate to a human dispatcher disposed distant from the dust control machine 18 and/or distant from a work location 14 that a dust control machine 18 should be dispatched to one or more specific work locations 14. The human dispatcher may respond to the indication by dispatching a dust control machine 18 to the specified work location(s) 14. For example, the human dispatcher may call the operator of a dust control machine 18 and instruct the operator to transport the dust control machine 18 to the specified work location(s) 14.

[31] In one embodiment, a controller 26 may receive a dust control signal 34 from a dust monitor 22 indicating that a dust level within a work location 14 is above a reference dust level. In another embodiment, the controller 26 may receive a plurality of dust control signals 34 from the dust monitor 22 over a period of time indicating that the dust level within the work location 14 will likely exceed a reference dust level if dust treatment is not performed. In either case, the controller 26 may issue a dispatch signal 42 for dispatching a mobile dust control machine 18 to the corresponding work location 14. Thus, the mobile dust control machine 18 may be dispatched to the work location 14 to perform a dust treatment operation within the work location 14, thereby suppressing or otherwise controlling a dust condition within the work location 14.

[32] The controller 26 may be operable to receive multiple dust control signals 34 from one or more dust monitors 22 indicating dust conditions at multiple work locations 14. The controller 26 may be operable to evaluate and compare the indicated dust conditions of the respective work locations 14 and to use the comparison to produce one or more appropriate dispatch signals 42 for dispatching one or more dust control machines 18 to one or more work locations 14. For example, the controller 26 may be operable to determine which of the

monitored work locations 14 have the highest dust levels and to produce one or more dispatch signals 42 in accordance with the determination. Moreover, the controller 26 may be operable to evaluate the indicated dust conditions of the respective work locations 14 and to determine a dispatch route for at least one of the dust control machines 18 based on the evaluation. In one embodiment, the controller 26 may be operable to compare dust control signals 34a, 34b, 34c of multiple work locations 14a, 14b, 14c and to dispatch a dust control machine 18a in sequence to each of the work locations 14a, 14b, 14c by giving dispatch priority to work locations having higher dust levels.

[33] In one example, the controller 26 may receive dust control signals 34a, 34b, 34c from multiple dust monitors 22a, 22b, 22c indicative of dust conditions within multiple work locations 14a, 14b, 14c. The controller may be operable to evaluate these signals 34a, 34b, 34c to determine (1) that a first work location 14a has the highest dust level, (2) that a second work location 14b has the second highest dust level, and (3) that the dust conditions of the first and second work locations 14a, 14b warrant dust treatment operations in those locations 14a, 14b. In response to the determination, the controller 26 may produce one or more dispatch signals 42 for dispatching a dust control machine 18a first to the first work location 14a and subsequently to the second work location 14b. Thus, the controller 26 may be operable to produce dispatch signal(s) 42 to indicate a desired (*e.g.*, the most efficient or otherwise most effective) dispatch route for the dust control machine 18a. Alternatively or additionally, the controller 26 may produce one or more dispatch signals 42 for dispatching a first one of the dust control machines 18a to the first work location 14a and for dispatching a second one of the dust control machines 18b to the second work location 14b.

[34] In accordance with the present invention, the locations of the mobile dust control machines 18 may be monitored. For example, GPS or other location monitoring equipment 24 may be provided on the mobile dust control

machines 18. Moreover, the locations of the mobile dust control machines 18 may be determined and communicated to the controller 26 via communication means, such as the communication means described above. In one embodiment of the present invention, the controller 26 may be operable to evaluate the location of a first dust control machine 18a relative to a work location 14a (or work locations) and/or relative to a second dust control machine 18b (or machines) and to produce a dispatch signal 42 for dispatching the dust control machine 18a to the work location 14a in response to the evaluation. For example, the controller may be operable to determine (1) that a dust condition at the work location 14a requires treatment, and (2) that the first dust control machine 18a is closer to the first work location 14a than is the second dust control machine 18b. Thus, the controller 26 may be operable to produce a dispatch signal 42 for dispatching the first dust control machine 18a (rather than the second dust control machine 18b) to the first work location 14a, thereby reducing overall travel distance and/or travel time for the dust control machines 18a, 18b and potentially reducing overall fuel consumption of the dust control machines 18a, 18b.

[35] Similarly, when multiple work locations 14 are being monitored, the controller 26 may be operable to evaluate and compare potential routes for a dust control machine 18 (or machines) and to produce one or more dispatch signals 42 indicating a preferred route (or routes) for the dust control machine(s) 18, for example by evaluating or estimating (and potentially minimizing) total estimated travel time, fuel consumption, and/or travel distance for the dust control machine(s) 18 and/or by evaluating dust conditions within the work locations 14. For example, the controller 26 may be operable to determine (1) that dust conditions within three work locations 14a, 14b, 14c warrant dust treatment operations; (2) that total travel distance and/or work time of two dust control machines 18a, 18b may be minimized by (a) dispatching the first dust control machine 18a first to the first work location 14a and subsequently to the second work location 14b and by (b) dispatching the second dust control machine

18b to the third work location 14c. Thus, a controller 26 may be operable to evaluate information regarding: (i) dust conditions within one or more work locations 14; (ii) the locations(s) of one or more dust control machines 18; and/or (iii) the location(s) of one or more work locations 14, and to dispatch one or more dust control machines 18 to the location(s) 14 in response to the evaluated information.

[36] In a further embodiment, a dust control machine 18b may include one or more resource status indicators 46 for indicating a status of one or more resources onboard the dust control machine 18b. For example, a resource status indicator 46 may be operable to indicate the amount of fuel available for consumption onboard the dust control machine 18b, and/or the resource status indicator may be operable indicate the amount of dust control resources (*e.g.*, water) available onboard the dust control machine 18b. Moreover, the resource status indicator(s) 46 may be operable to transmit resource status signals 50 to a controller 26, and the controller 26 may be operable to evaluate the resource status signals 50 in order to more effectively dispatch one or more dust control machines 18. For example, the controller 26 may be operable to evaluate the amount of resources available to one or more dust control machines 18 in order to effectively dispatch the dust control machine(s) 18.

[37] In one embodiment, a controller 26 may be operable to evaluate: (i) the amount of fuel available for use onboard one or more dust control machines 18; (ii) the amount of dust control resources (e.g., water) available onboard one or more dust control machines 18; (iii) the location(s) of one or more dust control machines 18 with respect to one or more work locations 14; and/or (iv) dust condition(s) at one or more work locations 14. The controller 26 may be operable to use this evaluation in order to effectively dispatch one or more dust control machines 18 to the one or more work locations 14. For example, the controller 26 may be operable to: (a) determine a dust condition (e.g., dust level) at a work location 14a; (b) calculate or otherwise estimate the

amount (and/or flow rate) of dust control resources (*e.g.,* water) required to effectively treat the dust condition (for example, using lookup tables, software, or other tools known in the art for such calculations); (c) determine the amount of fuel necessary to transport a dust control machine 18b (or machines) to the work location 14a (for example as a function of the fuel efficiency of the machine 18b and the distance between the dust control machine 18b and the work location 14a) and; (d) determine whether the dust control machine 18b (or machines) has sufficient onboard resources available (e.g.,fuel, water) to travel to the work location 14a and/or to effectively treat the dust condition at the work location 14a; and (e) dispatch the dust control machine 18b (or machines) to the work location 14a as a result of these determinations. Thus, the controller 26 may be operable to evaluate all information being transmitted to it regarding one or more dust control machines 18 and one or more work locations 14 and to use this evaluation to effectively dispatch the dust control machine(s) to the work location(s) -- for example by dispatching the dust control machine(s) along one or more routes that minimizes travel time, work time, fuel consumption, and/or other work factors. For example, the controller 26 may dispatch a first dust control machine 18b to a work location 14a even though a second dust control machine 18a is closer to the work location 14a if the second dust control machine 18a does not have sufficient resources (e.g., fuel or water) to travel to the work location 14a and completely treat the work location 14a.

[38] It should be appreciated that a controller 26 may be operable to evaluate a dust control machine's onboard resources and, in response to this evaluation, dispatch the dust control machine 18 to a refill location 54 so that the dust control machine 18 may refill its onboard resources. Moreover, a controller 26 may be operable to dispatch a relief dust control machine 18b to a work location 14a if, for example during the course of treating the work location 14a, a first dust control machine 18a exhausts or is likely to exhaust its onboard resources (e.g., water or fuel) before fully treating the work location 14a. In

addition, the controller 26 may be operable to dispatch one or more dust control machines 18 to one or more work locations 14 that may benefit from dust treatment operations in order to maximize the use of (e.g., deplete or nearly deplete) the dust control machine's 18 resources before dispatching the dust control machine 18 to a refill location 54, a maintenance location, or other location for refilling, scheduled maintenance, or other downtime activity.

[39] It should be appreciated that a dust control machine 18a may be operable to treat an intermediate work location 14 en route to a high priority work location 14a to which the dust control machine 18a has already been dispatched. For example, if a dust control machine 18a is en route to a high priority work location 14a and a mobile dust monitor 22e onboard the dust control machine 18a indicates that dust treatment operations are warranted at a work location 14 along the dust control machine's present path, the dust control machine 18a may perform dust treatment operations (for example in response to a new dispatch signal 42 from the controller 26) along its present path while en route to the high priority work location 14a.

[40] It should be appreciated that a dust monitor 22 may incorporate a controller 26 and may be operable to produce one or more dispatch signals 42 in response to monitoring a dust condition of a work location 14. It should further be appreciated that such dust monitor may be operable to receive one or more dust control signals 42 from one or more other dust monitors 22 and to provide all of the functions described above with respect to a controller 26.

[41] Operation of the system 10 may be controlled by software that is programmed into the controller 26 and/or various other components of the system 10. Alternatively or additionally, operation of the system 10 may be implemented via hardware or any other known programming or operating technique. Creation of appropriate software based upon the description set forth herein is within the capabilities of one having ordinary skill in the programming arts.

Industrial Applicability

[42] The present invention provides an improved system 10 and method for controlling work site dust more efficiently and effectively than prior systems and methods.

[43] According to the present invention, one or more dust control machines 18 may be selectively dispatched in real time among work locations 14 only when and where dust treatment operations are needed. For example, the present invention may be used to dispatch dust control machines 18 automatically to a work location 14 when dust levels at the work location 14 exceed, or are likely to exceed, a reference dust level. In addition, the present invention may provide a method for evaluating dust conditions at a plurality of work locations 14 and selectively dispatching one or more dust control machines 18 as appropriate, for example to one or more work locations 14 where dust control operations are more severely needed. Further, the present invention may provide a method for dispatching a dust control machine 14 to one or more work locations 14 according to the position of the dust control machine 18 relative to the work location(s) 14 and/or relative to other dust control machine(s) 18. Moreover, the present invention may provide a method for dispatching a dust control machine 14 to one or more work locations 14 according to the status of resources onboard the work machine 14 and/or according to the status of resources onboard another work machine 14. As a result of these and other features of the present invention, fuel, water, and other dust control resources may be used more efficiently and effectively, and dust treatment operations may be more effectively controlled.

[44] From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit or scope of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and figures and

practice of the invention disclosed herein. It is intended that the specification and disclosed examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims and their equivalents. Accordingly, the invention is not limited except as by the appended claims.